VARIATION OF NORTH AMERICAN FISHES.*

I.

THE VARIATION OF ETHEOSTOMA CAPRODES RAFINESQUE.

By W. J. Moenkhaus.

Etheostoma is a genus of American Freshwater Percidæ. It consists of about 100 species distributed in a number of subgenera. All the members of the genus are small. They are distributed over approximately the entire Atlantic slope of North America. The northernmost points are Fort Quappelle and Montreal; the southernmost, Chihuahua. The most west ern points are Colorado and Swift Current in Canada near the 108th meridian.

The subgenus Percina includes the largest of the darters. There are but two well-defined species. One, *Etheostoma rex* is known from east of the Alleghany Mountains. The other, *Etheostoma caprodes* is also found east of the Alleghanies, but its chief habitat is west of these mountains, where it is found from Lakes Champlain and Superior to the Rio Grande.

This latter species, *Etheostoma caprodes* Rafinesque, has been studied with a view to ascertain the extent of its variation, the relation of its variation to its geographical distribution, the extent of variation in each locality, and the variation with age. This species of the darters has been selected for its size, and on account of its wide distribution and moderate abundance within its limits. Its variability has been known for a long time, and has given it a number of specific names.

The material examined is recorded in the table of measurements and counts.

The greatest variation was found to be in the color. Slighter variations were found in proportions and number of fin rays.

* Contributions from the Zoological Laboratory of Indiana University, under the direction of Carl H. Eigenmann, No. 10.

Evolution of the Color Pattern.

As just stated, the point of greatest variability is the color pattern. The colors in life are not taken into consideration, but only the black markings which were preserved in alcoholic specimens. On comparing living specimens with alcoholic material, but little difference was noticed. In the matter of color patterns, the specimens from any one locality agree to a remarkable extent. This statement refers only to specimens of the same size—differences, of course, existing between young and adult stages.

The simplest pattern was found in specimens from Chocola Cr., Ala. These were immature specimens, and do not represent the adult condition.

In these specimens (30 and 33 mm. long., fig. 1), we have a series of nine cross-bars extending from the back to below the middle of the sides. The bars at the ends of the dorsal fins are much emphasized, and all the bars are heaviest at their upper and lower ends. There is a distinct round spot at the root of the caudal. The color of the head need not be taken into consideration in this specimen. The caudal spot remains in all the specimens examined. The most complicated pattern, that of fig. 7, is shown to be derived by easy stages and step by step from the condition figured in fig. 1.

The simplest pattern in adult fishes is found in specimens inhabiting the waters of the Wabash River and its tributaries in Indiana (Nos. 9, 40 and 44). The pattern here consists of a series of long and short bars alternating. In the anterior region, the short bars are usually as long as the long bars. A better way to designate these is to term the long bars "whole bars," and the short bars "half bars." The whole bars towards the posterior end of the body spread slightly and become more intensely colored toward their ventral extremity. The black caudal spot is also present here. This spot does not vary in any of the patterns figured. The head is colored black above, and has a large spot on the opercle, taking the general form of the opercle itself. The color on the top of the head is most intense towards the posterior, as shown in fig. 9, and becomes less less distinct as it extends forward to the tip of the snout.

Around the eyes are seen faint indications of three bars: one extending forward; the second downward, and the third backward (fig. 2).

Comparing this pattern with the one in the young, we find that the whole bars are homologous in the two, and that the half bars have been added.

A step in advance is taken by the adult specimens from Chocola Cr., Ala., fig. 3 (Nos. 76–82). These have the bars alternately long and short along the entire length of the body. The bars are considerably broader and more intense, and the whole bars have their ventral extremities much broadened, so as to form quite an apparent series of spots along the side. An additional half bar is added by the union of the spot above and the spot just in front of the black caudal spot. Here the three bars radiating from the eye are somewhat more distinct than in the pattern already described.

The next series of individuals are Nos. 45–55, 72, 73 and 75, in the list given below, and are represented by fig. 4. They are found in the Green, Cumberland, Tennessee and Arkansas River Basins. The color pattern here shows a greater irregularity in its bars, and has developed in addition a still shorter between each of the whole and half bars of the preceding pattern, so that we have now whole, half and quarter bars. The series of lateral spots is present only along a part of the body. The bar extending anteriorly from the eye is broken into two shorter and less distinct ones.

Of considerable significance in the specimen figured in fig. 3 is the fact that in the bar between the dorsals, we have a notch indicating that some of the color-cells are separating from the whole bar. A similar condition is shown in the same region of fig. 4. The quarter bars are apparently split off from the other bars. It is of interest that variations in the direction of an increased number of bars is always, as far as my specimens go, introduced at this point. Specimens intermediate between this and the preceding form show that the quarter bars always make their first appearance between the seventh and eighth whole bars and the included half bar.

Other quarter bars are then added in front and behind this region.

From the conditions represented in fig. 3, we have two diverging lines of development. The one line was discussed in the preceding paragraph. The other line is found in specimens, Nos. 82 and 83, taken from San Marcos Spring, Texas, and is represented in fig. 5. We have here a splitting of the bars without the regular result seen in fig. 4. The lower ends of the whole bars have not split, in fact, they have increased in width, and form a very prominent series of spots along the side. It will be seen that the bars radiating from the eye have become much more pronounced.

The pattern of fig. 6 can be easily derived from the preceding one by assuming that the lower half of the whole bars of the anterior part of the body have shifted their position backward, so that they no longer extend extirely to the mid-dorsal line. The 3d, 4th and 5th whole bars show different degrees of shifting. The lower part of the 4th has shifted, but still retains its connection with the upper part. In the 3d, the bar is more nearly separated, while in the 5th the separation is complete, and the original lower part of the bar becomes simply a vertically elongated spot. The bars around the eye are here again less developed. The pattern of fig. 6 is the one occurring in *Etheostoma caprodes manitou* Jordan, and was drawn from a specimen taken from Torch Lake, Mich. Other specimens, taken from the same lake and from other localities, have the same color pattern with slight variations. Nos. 1–7, and 41 of Table I, are this variety.

The line of development taken up by fig. 5 is continued in figs. 7 and 8, representing the specimens from Obey's River and Eagle Creek in Tennessee, and from the Little South Fork of the Cumberland River in Kentucky. These are Nos. 56–72 in the table. A single young specimen, No. 74, which promised to become this form, was also taken in the North Fork of the Holston River, in Virginia. The two figures were drawn from a younger and older specimen respectively, of the same form. In the younger specimens, the bars have become more split up, and have increased in irregularity. Almost all of

the original bars, however, can be traced. The lateral spots, too, are much more prominent than in the preceding pattern. In the older individuals the bars have become so much split up as to form a complicated network, and the original pattern can be made out only in a general way. The spots are larger and darker than in the younger, and form almost a continuous lateral band. The radiating bars around the eyes are correspondingly more developed, the one extending backward in a slight curve beyond the head to the first lateral spot.

In the last pattern, the original simple whole and half bars have reached their greatest modification, and the faint lateral spots of fig. 2 have become the most prominent part of the coloration.

The variation presents a serial modification in two divergent lines from an original simplest pattern. Beginning with the whole bars of fig. 1, we pass to the form having alternate whole and half bars, and an imperfect series of lateral spots. From this form we pass on the one hand to the pattern having alternate whole, half and quarter bars, and on the other hand to the pattern consisting of reticulated markings above, and a very prominent series of spots along the sides. In the pattern of fig. 6, we have a second divergent line of development from fig. 5. The radiating bars around the eyes become more developed as we pass from the simple to the more complex patterns, with the exception in fig. 6.

It will be seen from the localities at which each of the various patterns occurred, that there is no definite serial relation between the variations and the latitude at which they are found. As already stated, however, the variations are remarkably definite for a given locality. The specimens from the Wabash waters can, almost without exception, be distinguished from those of the Cumberland River, for instance, while those from the Alabama River are distinguished by their invariably broader bars. Both the patterns of figs. 4 and 6 occur in the Cumberland and Tennessee River system, but both have not been taken from the same tributaries of these streams.

The color pattern of *Etheostoma caprodes* is of interest when considered as to its bilateral symmetry. In most of the sim-

plest patterns, the corresponding bars on the two sides are exactly alike, and precisely meet each other in the mid-dorsal tine. This almost perfect symmetry is not so prevalent in the more complex patterns. The simplest cases of asymmetry are found in the simplest patterns when some of the bars do not exactly meet their fellows on the back. Fig. 8 shows an instance of this kind. Both the asymmetrical and the symmetrical forms occur in the same locality, and the former seems purely accidental, but in all cases observed, it makes its first appearance in the bars along the spinous dorsal. From this point it spreads backward along the soft dorsal until we reach an extreme form of asymmetry, as represented in fig. 9. Here the first three and the last four bars, together with the bar between the dorsals, still preserve their symmetry, while those along the entire length of both dorsals are quite asymmetrical.

In regard to variations in parts other than in the color pattern, only those points of structure were examined that could be most accurately made out on alcoholic specimens. One very marked departure from the regular form exists in the specimens from San Marcos Spr., Texas. This departure consists, as shown in fig. 5, of an increase in the depth of the body in the region of the spinous dorsal, as a result of the unusual elevation of the back in this region. These belong to the variety carbonaria, described from Texa, and are more distinct in points of form than the varieties I examined from any other locality.

No. 8 in Table I, taken by Dr. Meek at Cedar Rapids, Iowa, differs materially from any of the specimens from other localities. It approaches nearest the variety zebra in the color pattern, and in having no scales before the spinous dorsal. The scales, however, are larger, there being but 76 in the lateral line. The head measures $3\frac{1}{2}$ in body and the number of rays in anal is 12.

The following table will give the number of specimens, their locality and the points of structure which have been examined. The spines in the dorsal and anal fins are indicated by Roman numbers and the rays by Arabic numbers. The length of the

specimens are measured in mm. from the tip of the snout to root of caudal. Only those scales of the lateral line are counted which have the tribes developed in them. The localities are arranged in the order of their latitude from north to south.

TABLE I.

Locality.	Figures representing these types.	Length of body in mm.	Length of head in mm.	Head in body.	Dorsal fin.	Anal fin.	Scales in lateral line.
1. Torch Lake, Mich.	6	77	19	$4\frac{1}{19}$	XIV,15	II,10	90
2. " " "	6	76	19	4	XIV,15	II,10	90
3. " " "	6	80	20	4	XV,15	II,10	85
4. " " "	6	75	$18\frac{1}{2}$	$4\frac{1}{18}$	XV,15	II,10	89
5. " " "	6	80	20	4	XV,15	II,10	90
6. " " "	6	77	19	$4\frac{1}{19}$	XIV,14	II,10	90
7. " " "	6	73	18	$4\frac{1}{18}$	XV,16	II,11	90
8. Cedar Rapids, Iowa	6	70	20	$3\frac{1}{2}$	XIV,15	II,12	76
9. White River, Indianapolis, Ind.	2				XIV,16	II,10	86
10. Racoon Creek, Mecca, Ind.	2	40	$10\frac{3}{4}$	$3\frac{9}{10}$			89
11. " " " "	2	42	11	$3\frac{9}{11}$			90
12. " " " "	2	41	11	$3\frac{8}{11}$			90
13. Gosport, Ind.	2	90	21	$4\frac{2}{7}$	XV,15	II,10	90
14. " "	2	50	13	$3\frac{11}{13}$	XIV,15	II,10	88
15. " "	2	38	10	$3\frac{4}{5}$	XV,15	II,10	90
16. " "	2	47	13	$3\frac{8}{13}$	XV,15	II,10	87
17. " "	2	53	14	$3\frac{11}{15}$	XV,15	II,10	90
18. Bean Blossom, Ind.	2	67	17	$3\frac{16}{17}$	XV,16	II,10	87
19. " " "	2	84	22	$3\frac{4}{11}$	XIV,16	II,11	90
20. " " "	2	94	24	$3\frac{11}{12}$	XIV,17	II,11	88
21. " " "	2	$86\frac{1}{2}$	$22\frac{1}{2}$	$3\frac{9}{22}$	XV,16	II,11	85
22. " " "	2	83	21	$3\frac{20}{21}$	XIV,16	II,11	86
23. " " "	2	113	27	$4\frac{5}{27}$	XV,15	II,11	86
24. " " "	2	$71\frac{1}{2}$	$18\frac{1}{2}$	$3\frac{17}{18}$	XIV,16	II,10	88
25. " " "	2	82	$21\frac{1}{2}$	$3\frac{16}{21}$	XIV,16	II,10	87
26. " " "	2	77	21	$3\frac{2}{3}$	XV,16	II,11	88
27. " " "	2	71	18	$3\frac{8}{9}$	XIV,16	II,11	88
28. " " "	2	61	16	$3\frac{3}{4}$	XV,16	II,10	87
29. " " "	2	44	11	4	XIV,16	II,11	85
30. " " "	2	42	11	$3\frac{9}{11}$	XV,16	II,10	86
31. " " "	2	47	13	$3\frac{8}{13}$	XIII,16	II,10	85
32. " " "	2	96	24	4	XV,15	II,11	88
33. " " "	2	73	18	$4\frac{1}{18}$	XIV,16	II,10	85
34. " " "	2	68	17	4	XIV,16	II,10	86
35. " " "	2	35	10	$3\frac{1}{2}$			
36. " " "	2	33	9	$3\frac{2}{3}$			
37. Rushville, Ind.	2	88	22	4	XIV,15	II,10	90
38. Wild Cat Creek, Kokomo, Ind.	2	130	32	$4\frac{1}{16}$	XV,16	II,11	85

Locality.	Figures representing these types.	Length of body in mm.	Length of head in mm.	Head in body.	Dorsal fin.	Anal fin.	Scales in lateral line.
39. Pike Creek, Ind.	2	107	26	$4\frac{3}{26}$	XIV,16	II,11	89
40. " " "	2	102	25	$4\frac{2}{25}$	XV,16	II,11	91
41. Illinois	2	65	15	$4\frac{1}{3}$	XV,14	II,10	89
42. Nipisink Lake, Ills.	2				XV,15	II,10	85
43. " " "	2				XIV,15	II,11	85
44. Monongahela River, Pa.	4	96	23	$4\frac{2}{23}$	XV,15	II,10	85
45. Hartford, Ky.	4	76	19	4	XVI,14	II,10	88
46. " "	4	76	19	4	XV,15	II,10	87
47. " "	4	76	19	4	XIV,16	II,10	88
48. " "	4	78	$19\frac{1}{2}$	4	XV,16	II,11	90
49. Green River, Greensburg, Ky.	4	85	20	$4\frac{3}{20}$	XV,15	II,10	89
50. " " " "	4	90	$21\frac{1}{2}$	$4\frac{4}{21}$	XV,16	II.11	92
51. " " " "	4	77	$17\frac{1}{2}$	$4\frac{7}{19}$	XV,15	II,11	85
52. Little Barren River, Osceola, Ky.	4	92	23	4	XV,15	II,11	89
53. " " " " "	4	69	17	$4\frac{1}{17}$	XV,14	II,11	89
54. " " " " "	4	69	17	$4\frac{1}{17}$	XVI,15	II,11	89
55. " " " " "	4	69	17	$4\frac{1}{17}$	XIV,16	II,11	83
56. Little S. Fork Cumberland River, Wayne Co., Ky.	7 & 8	103	25	$4\frac{1}{8}$	XVI,15	II,11	92
57. Eagle Creek, Olympus, Tenn.	7 & 8	82	21	$3\frac{19}{21}$	XVII,14	II,11	87
58. " " " "	7 & 8	$61\frac{1}{2}$	16	$3\frac{13}{16}$	XVI,15	II,11	92
59. Obey's River, " "	7 & 8	77	18	$4\frac{5}{18}$	XVII,14	II,11	89
60. " " " "	7 & 8	86	21	$4\frac{2}{21}$	XV,14	II,10	86
61. " " " "	7 & 8	55	$13\frac{1}{2}$	$4\frac{1}{13}$	XVI,15	II,12	89
62. " " " "	7 & 8	66	17	$3\frac{15}{17}$	XVI,15	II,12	90
63. " " " "	7 & 8	62	15	$4\frac{2}{15}$	XVII,15	II,12	87
64. " " " "	7 & 8				XVII,15	II,11	90
65. " " " "	7 & 8	65	$16\frac{1}{2}$	$3\frac{15}{16}$	XV,17	II,11	90
66. " " " "	7 & 8	53	14	$3\frac{11}{14}$	XVI,15	II,11	89
67. " " " "	7 & 8	54	$13\frac{1}{2}$	4	XVII,15	II,12	86
68. " " " "	7 & 8	60	15	4	XVII,15	II,12	91
69. " " " "	7 & 8	$51\frac{1}{2}$	$12\frac{1}{2}$	$4\frac{1}{12}$	XVII,14	II,12	85
70. " " " "	7 & 8	$53\frac{1}{2}$	13	$4\frac{1}{13}$	XVII,15	II,12	89
71. " " " "	7 & 8	$57\frac{1}{2}$	$14\frac{1}{2}$	4	XVII,15	II,11	90
72. Watauga River, Elizabethtown, Tenn.	4	122	27		XVI,16	II,11	92
73. " " "	4	94	21		XV,16	II,10	92
74. North Fork Holston River, Saltville, Va.	7 & 8	$47\frac{1}{2}$	13	$3\frac{9}{13}$	XVI,15	II,12	92
75. Eureka Springs, Ark.	4	112	24	$4\frac{2}{3}$	XVI,15		
76. Chocola Creek, Oxford, Ala.	3	94	21	$4\frac{10}{21}$	XVI,15	II,11	91
77. " " " "	3	97	18	$4\frac{5}{18}$	XV,17	II,12	78
78. " " " "	3	89	21	$4\frac{5}{21}$	XVI,17	II,11	93
79. " " " "	3	78	17	$4\frac{10}{17}$	XV,15	II,11	90
80. San Marcos Spring, Texas	5	95	21	$4\frac{11}{21}$	XIII,15	II,11	85
81. " " " "	5	102	24	$4\frac{1}{3}$	XIV,15	II,11	93
82. " " " "	3	27	7	$3\frac{6}{7}$			
83. " " " "	3	30	8	$3\frac{3}{4}$			

Table II presents all the combinations of dorsal spines and dorsal rays, and the number of specimens having the given combination. (But 76 of the specimens have been examined for this table.) The combinations are arranged in the numerical order of the spines from the lowest number to the highest. In the third column are given the per cents. of specimens having each combination. XV, 15 is seen to be the commonest combination; XIV, 16 the next, XV, 16 and XVI, 15 the next, and so on. The largest per cent. of any combination does not exceed 21.052.

TABLE II.

Dorsal Fins.	Number of specimens.	er cent. of specimens.
XIII, 15	1	1.315
XIII, 16	1	1.315
XIV, 14	2	2.631
XIV, 15	6	7.895
XIV, 16	12	15.789
XIV, 17	1	1.315
XV, 14	3	3.947
XV, 15	16	21.05
XV, 16	11	14.47
XV, 17	2	2.631
XVI, 14	1	1.315
XVI, 15	9	11.841
XVI, 16	1	1.315
XVI, 17	1	1.315
XVII, 14	3	3.947
XVII, 15	6	7.894

In Table III are arranged the varieties in the number of dorsal spines, the number of specimens representing each variation, and the per cent, of all the specimens for each variation. The average number of spines is $15\frac{5}{76}$, while the number of spines predominating is 15.

TABLE III.

Dorsal Spines.	Number of specimens.	Per cent. of specimens.
XIII	2	2.631
XIV	21	27.63
XV	32	42.11
XVI	12	15.789
XVII	9	11.841
Average number of spines		$15\frac{5}{76}$

In Table IV the same data are given for the dorsal rays. The average number of rays is $15\frac{6}{19}$, about the same as the spines. Fifteen is seen to be the number in about 50 per cent. of all the specimens examined. While 42.11 per cent. have fifteen dorsal spines, and 50.007 per cent. have fifteen dorsal rays, only 21.05 per cent. have a combination of fifteen spines and fifteen rays.

TABLE IV.

Dorsal Rays.	Nnmber of specimens.	Per cent. of specimens.
14	9	11.841
15	38	50.007
16	25	32.90
17	4	5.262
Average number of rays		$15\frac{6}{19}$

The variations in the anal fin are given in Table V. The anal fins of only 76 specimens were examined.

TABLE V.

ANAL FINS.	Number of specimens.	Per cent. of specimens.
II, 10	30	39.47
II, 11	36	47.37
II, 12	10	13.15
Average number of anal rays.....		$10\frac{14}{19}$

In Table VI are given the variations in the number of scales in the lateral line. The scales were counted on 79 specimens. Eighty-five was the number fonnd in a number having the lateral line incompletely developed. Eighty-five, eighty-eight, eighty-nine and ninety were found in about 60 per cent. of the specimens examined.

TABLE VI.

SCALES WITH PORES.	Per cent. of specimens.	Number of specimens.
76	1	1.265
78	1	1.265
83	1	1.265
85	12	15.20
86	7	8.86
87	7	8.86
88	8	10.12
89	12	15.20
90	18	22.77
91	3	3.80
92	7	8.86
93	2	2.53
Average number of scales......		$88\frac{11}{79}$

Table VII indicates the number of specimens, the average number of dorsal spines, and the number of specimens with thirteen, fourteen, fifteen, sixteen and seventeen spines from each of the localities from which specimens were examined. The localities are arranged as they occur, from north to south. It will be seen that the prevailing numbers occurring in the more northern streams are fourteen and fifteen. As we go farther south the usual number is fifteen and sixteen, and in the most southern streams the numbers are fifteen, sixteen and seventeen spines, the specimens from Texas are peculiarly poor in the number of spines.

TABLE VII.

Locality.	Number of specimens.	Average number of dorsal spines.	Number of specimens with 13.	Number of specimens with 14.	Number of specimens with 15.	Number of specimens with 16.	Number of specimens with 17.
Torch Lake, Mich	7	$14\frac{4}{7}$		3	4		
Cedar Rapids, Ia	1	14		1			
White River, at Indianapolis	1	14		1			
Gosport, Ind	5	$14\frac{4}{5}$		1	4		
Bean Blossom, Ind	17	$14\frac{6}{17}$	1	9	7		
Rushville, Ind	1	14		1			
Wild Cat Creek, Ind	1	15			1		
Pike Creek, Ind	2	$14\frac{1}{2}$		1	1		
Illinois	1	15			1		
Nipisink Lake, Ill	2	$14\frac{1}{2}$		1	1		
Monongahela River	1	15			1		
Hartford, Ky	4	15		1	2	1	
Green River, Greensburg, Ky	3	15			3		
Little Barren River, Osceola, Ky	4	15		1	2	1	
Little South Fork Cumberland River, Wayne Co., Ky	1	16				1	
Eagle Creek, Olympus, Tenn	2	$16\frac{1}{2}$				1	1
Obeys River, Elizabethtown, Tenn	13	$16\frac{6}{13}$			2	3	8
Watauga River, " "	2	$15\frac{1}{2}$			1	1	
North Fork Holsten River, Saltville, Va.	1	16				1	
Eureka Springs, Ark	1	16				1	
Chocola Creek, Oxford, Ala	4	$15\frac{1}{2}$			2	2	
San Marcos Springs, Tex	2	$13\frac{1}{2}$	1	1			

Table VIII contains the same data with regard to the dorsal rays. In the last column is given the average number of dorsal spines and rays combined. The rays do not show the same variation found in the dorsal spines, the number being the same for localities north and south. The average number of dorsal spines and rays combined consequently increases with the dorsal spines.

TABLE VIII.

Locality.	Number of specimens.	Average number of dorsal rays.	Number of specimens with 13.	Number of specimens with 14.	Number of specimens with 15.	Number of specimens with 16.	Number of specimens with 17.	Av. num. of dorsal rays & spines.
Torch Lake	7	15		1	5	1		$29\frac{4}{7}$
Cedar Rapids, Ia.	1	15			1			29
White River, at Indianapolis	1	16				1		30
Gosport, Ind.	5	15			5			$29\frac{4}{5}$
Bean Blossom, Ind.	17	$15\frac{16}{17}$			2	14	1	$30\frac{5}{17}$
Rushville, Ind.	1	15			1			29
Wild Cat Creek, Ind.	1	16				1		31
Pike Creek, Ind.	2	16				2		$30\frac{1}{2}$
Illinois	1	14		1				29
Nipisink Lake, Ill.	2	15			2			$29\frac{1}{2}$
Monongahela River	1	15			1			30
Hartford, Ky.	4	$15\frac{1}{4}$		1	1	2		$30\frac{1}{4}$
Green River, Greensburg, Ky.	3	$15\frac{1}{3}$			2	1		$30\frac{1}{3}$
Little Barren River, Osceola, Ky.	4	15		1	2	1		30
Little South Fork Cumberland River, Wayne Co., Ky.	1	15			1			31
Eagle Creek, Olympus, Tenn.	2	$14\frac{1}{2}$		1	1			31
Obeys River, Elizabethtown, Tenn.	13	$14\frac{12}{13}$		3	9		1	$31\frac{5}{13}$
Watauga River, " "	2	16				2		$31\frac{1}{2}$
North Fork Holston River, Saltville, Va.	1	15			1			31
Eureka Springs, Ark.	1	15			1			31
Chocola Creek, Oxford, Ala.	4	16			2		2	$31\frac{1}{2}$
San Marcos Spring, Tex.	2	15			2			$28\frac{1}{2}$

Table IX gives similar data on the anal fins. The spines are not given since they were found to be two in all cases examined. In the anal rays we have, as in the dorsal spines, a slight increase in their number from north to south. The

most common number in the Indiana streams is ten, the number increasing to eleven and twelve in the most southern specimens.

TABLE IX.

Locality.	Number of specimens.	Average number of anal rays.	Number of specimens with 10 rays	Number of specimens with 11 rays	Number of specimens with 12 rays
Torch Lake	7	$10\frac{1}{7}$	6	1	
Cedar Rapids, Ia	1	12			1
White River, at Indianapolis	1	10	1		
Gosport, Ind	5	10	5		
Bean Blossom, Ind	17	$10\frac{9}{17}$	8	9	
Rushville, Ind	1	10	1		
Wild Cat Creek, Ind	1	11		1	
Pike Creek, Ind	2	11		2	
Illinois	1	10	1		
Nipisink Lake, Ill	2	$10\frac{1}{2}$	1	1	
Monongahela River	1	10	1		
Hartford, Ky	4	$10\frac{1}{4}$	3	1	
Green River, Greensburg, Ky	3	$10\frac{2}{3}$	1	2	
Little Barren River, Osceola, Ky	4	11		4	
Little South Fork Cumberland R., Wayne Co., Ky.	1	11		1	
Eagle Creek, Olympus, Tenn	2	11		2	
Obeys River, Elizabethtown, Tenn	13	$11\frac{6}{13}$	1	5	7
Watauga River, " "	2	$10\frac{1}{2}$	1	1	
North Fork Holston River, Saltville, Va	1	12			1
Eureka Springs, Ark	1				
Chocola Creek, Oxford, Ala	4	$11\frac{1}{4}$		3	1
San Marcos Springs, Tex	2	11		2	

Synonymy, Bibliography and Distribution of Etheostoma Caprodes Rafinesque.

Sciæna caprodes Rafinesque, "Amer. Month. Mag., 1818, 534."

Etheostoma caprodes Raf., "Ich. Oh., 1820, 38." Kirtland, Zool, Ohio, 1838, 168, 192; Bost. Jour, Nat. Hist., III, 346, 1841. (Ohio); Storer, "Synop. Fish. N. A., 1847, 270–272." Evermann, Bull. No. 2. Brookville Soc. Nat. Hist., 1886, 8. (Little Cedar Cr., Ind.); Evermann & Bollman, Notes on Coll.

Fish. from Monongahela R., 1886; Jenkins, Proc. Terre Haute Sci. Soc., 1886. (Streams of Vigo Co., Ind.); Evermann & Jenkins, Proc. U. S. Nat. Mus., 1888, 51–57. (Tippecanoe R., Wabash R., Deer Cr., Little Deer Cr., Wild Cat Cr., Fourteen Mile Cr., Clarke Co., Ind.); Meek, Proc. U. S. Nat. Mus., XI, 1888, 440. (Maumee R., Defiance Co., O.); Jordan, Bull. U. S. Fish Com., 1888, 147, 153, 159, 164, 167. (White R., at Spencer, Ind.); Mackey's Ferry, Posey Co., Ind; Wabash R., Vincennes, Ind.; Patoka R., at Patoka, Gibson Co., Ind.; Black R., New Harmony, Ind.; Wabash R., at New Harmony, Ind.; Eel River, Logansport, Ind.; Swannanoa R., at Asheville, N. C.; Watauga R., Elizabethton, Tenn.; North Fork of Holston R., (near Glade Spr.,Va.); Bollman, Bull. U. S. Fish Com., 1888, 224. (Cognac and Torch Lakes, Mich.; Spencer Cr., Calhoun Co., Mich.); Henshall, Journ. Cin. Soc. Nat. Hist., 1888, 80. (Little Miami R., and Ross L., O.); Meek, Bull. U. S. Fish Com., IX, 1889, 123, 128, 130, 139. (Gasconade R., at Arlington, Mo.; Spadra Cr., at Clarkesville, Ark.; James R., near Springfield, Mo.); Gilbert, Bull. U. S. Fish Com., 1889, 151, 155. (Ala. R., Tenn. R.); Jordan, Bull. U. S. Fish Com., 1889, 18. (Arkansas R., at Wichita); Jordan, Man. Vert., 1890, 126. (Gr. Lakes to Va., Ala. and Texas); Kirsch, Bull. U. S. Fish Com., 1891, 260, 261, 262, 264, 265, 266, 268. (Southern Trib. Cumb. R. in Tenn. and Ky.); McCormick, Lab. Bull. No. 2, Oberlin College, O., 1892. (Waters of Loraine Co., O.); Evermann & Kendall, Bull. U. S. Fish Com., 1894, 84, 88, 93, 113, pl. XXXV. (Long L., near Magnolia Point; Nechec R., east of Palestine.)

Pileoma caprodes Agassiz, L. Superior, 1850, 308; Le Vaillant, "Recherches sur les Poissons, etc., 1873."

Percina caprodes Girard. "Proc. Acad. Nat. Sci., Phila., 1859, 66;" Putnam, "Bull. M. C. Z., 1863, 5;" Cope, Proc. Acad. Nat. Sci., Phila., 1865, 82; Cope, Journ. Acad. Nat. Sci,, Phila., 1869, 211; Jordan, Ind. Geol. Sur., 1874, 213; Man. Vert., 1876, 224; Bull. Buffalo Soc. Nat. Hist., 1876, 93; Jordan & Copeland, Am. Nat., 1876, 337; Bull. Buffalo Soc. Nat. Hist., 1876, 135; Jordan, Proc. Acad. Nat. Sci., Phila., 1877, 44, 53, 54. (Low· Wabash R., White R.); Jordan, Ann. N. Y. Lyc. Nat. Hist.,

1877, 312, 373, 376. (Etowah, Oostanaula and Coosa Rivers, Ga.; Rock Castle R., S. E. Ky.; White R., at Indianapolis); Jordan, Bull. U. S. Nat. Mus. No. 9, 1877, 15, 24. (Notes on Nomenclature); Jordan, Bull. U. S. Nat. Mus. No. 10, 1877, 15. (Gr. Lake Region to Alabama); Jordan & Brayton, Bull. U. S. Nat. Mus. No. 12, 1878, 45, 57, 73. (Ala. R., Tenn. R., Cumb. R.); Jordan, Bull. 2 Ills. State Lab. Nat. Hist., 1878, 3. (Vermilion R., Calumet R., Wabash R., Pine Cr., Mo.); Jordan, Geo. Surv. of Ohio, IV, 1878, 970. (Quebec to Georgia, Lake Superior, and the Rio Grande); Jordan, Bull. U. S. Geo. Surv., 1879, 438. (Gr. Lake Region to Ala.); Hay, Proc. U. S. Nat. Mus., III, 1880, 491. (Chickasawha R., Miss.); Bean, Proc. U. S. Nat. Mus., III, 1880, 100. (Meadville, Penn., Racine, Wis., Columbus, O., Westport, N. Y., Poland, O., Yellow Cr., O., Madrid, N. Y., Ohio, Potomac R., Penn.); Cope, Report of State Fish Com. Pa., 124. (Lake Erie and Allegheny R., east to Lake Champlain); Hay, Bull. U. S. Fish Com., II, 1882, 60. (Vicksburg and Jackson, Miss.); Jordan & Gilbert, Syn. Fish North America, 499, 1883. (Gr. Lakes and streams of the South and West); Forbes, Rept. Ills. State Fish Com., 1884, 65. (L. Mich. to Cairo and Wabash Valley); Gilbert, Proc. U. S. Nat. Mus., VII, 1884, 204. (Salt Cr., near Bedford, Ind.); Jordan, Ann. Rept. Com. Fish and Fisheries, 1884, 79; Eigenmann & Fordice, Proc. Acad. Nat. Sci., Phila., 1885, 411. (Bean Blossom Cr., Ind.); Jordan & Eigenmann, Proc. U. S. Nat. Mus., 1885, 68; Jordan & Gilbert, Proc. U. S. Nat. Mus., 1886, 5, 8, 13, 21. (White R., near Eureka Springs; Trib. of Ark. R., near Ft. Smith; Washita R., at Arkadelphia, and Saline R., at Benton, Ark.; Rio San Marcos, at San Marcos, Tex.; Colorado R., at Austin, Tex.); Gilbert, 3d Series of Notes on Kansas Fish, ed. 1887, 207. (Inokomo Cr., Kans.)

Percina nebulosa Haldeman, "Journ. Acad. Nat. Sci., Phila., VIII, 1842, 330;" Girard, Proc. Acad. Nat. Sci., Phila., 1859, 66.

Perca nebulosa DeKay, "Fishes of N. Y., 1842, 7."

Etheostoma nebulosa Storer, "Synop. Fish N. A., 1847, 270–272."

Pileoma semifasciatum DeKay, N. Y. Fauna Fish., 1842, pl. 50, 162; Günther, I, 76, 1859. (Lake Erie and Ohio.)

Etheostoma semifasciata Storer, "Synop. Fish N. A., 1847, 270–272."

Percina semifasciata Girard, Proc. Acad. Nat. Sci., Phila., 1859, 66; Gill, Proc. Acad. Nat. Sci, Phila.. 1860, 20.

Pileoma carbonaria Baird & Girard, "Proc. Acad. Nat. Sci., Phila.," 1853, 387; Girard, U. S. and Mex. Bound. Surv., 10, 1859, pl. VIII, fig. 10–13. Rio Salado, Rio Medina, San Pedro Cr., Tex.); Günther, I, 76, 1859. (Rio Salado, Tex.)

Percina carbonaria Girard, "Proc. Acad. Nat. Sci., Phila., 1859, 67;" Jordan, Proc. Acad. Nat. Sci., Phila., 1877, 54. (Alabama R.); Jordan, Bull. U. S. Nat. Mus. No. 10, 1878, 15. (Texas); Jordan, Ann. N. Y. Lyc. Nat. Hist., 1878, XI, 312. (Alabama R.); Jordan, Bull. U. S. Geo. Surv., 1879, 438. (Texas).

Percina caprodes carbonaria Cope, Bull. 17, U. S. Nat. Mus., 1880, 31. (Trinity R., near Dallas, and Llano R., Kimble Co., Tex.)

Percina bimaculata Haldeman, "Proc. Bost. Soc. Nat. Hist., 1843, 157."

Etheostoma bimaculata Storer, "Synop. Fish N. A., 270–272, 1847."

Pileoma zebra Agassiz, Lake Superior, 308, pl. 4, fig. 4, 1850. (Lake Superior.)

Percina zebra Girard, Proc. Acad. Nat. Sci., Phila., 1859, 66. (Lake Superior); Jordan Bull. U. S. Nat. Mus. No. 10, 1877, 15. (Gr. Lake Region.)

Asproperca zebra Heckel.

Percina caprodes zebra Jordan, Ann. Rept. Com. Fish and Fisheries, 1884, 79.

Percina manitou Jordan, Proc. Acad. Nat. Sci., Phila., 1877, 53. (Lake Manitou in N. Indiana); Jordan, Bull. U. S. Nat. Mus. No. 10, 1877, 15. (Indiana to Minnesota); Jordan, Bull. 2 Ills. State Lab. Nat. Hist., 1878, 3. (L. Manitou, Ind., Wis.); Jordan, Bull. U. S. Geo. Surv., 1879, 438. (Indiana to Minne-

sota); Jordan, Geo. Surv. of Ohio, IV, 1878, 971. (Lakes of N. Ind., Mich. and Wis.)

Percina caprodes manitou Jordan & Gilbert, Syn. Fish. N. Am., 500, 1883. (Potomac R., Ills., Wis.); Jordan, Man. Vert., 1890, 126. (E. and N. U. S.)

To illustrate the distribution, the localities contained in the works quoted in the bibliography have been marked in the accompanying map.

The localities from which I examined specimens have been marked ♂. The areas inhabited by the various color patterns, as determined by my specimens, and by reports containing sufficiently minute descriptions, are indicated on the map by broken lines. The patterns distributed in each area is indicated by the number of the figure in the plates representing the pattern. In some cases it could not be determined which pattern occurred at the locality. There are some localities on the map, therefore, that are not included in any of the marked areas.

In conclusion, it may be observed:

1. The variation between specimens of the same locality is very slight.

2. The most complicated color pattern can be connected with the simplest by a series of intermediate stages.

3. The variation in color pattern cannot be connected with the latitude inhabited by the different varieties. The color variation is determined, but not in a direct line north and south.

4. The simplest color pattern of the body, found only in immature specimens, consists of nine transverse bars.

5. The simplest color pattern of adults consists of the nine bars seen in the young plus half bars between each two of the primary bars.

6. The next complication arises by the addition of quarter bars. These bars are first introduced in the region between the two dorsals, from which region variation seems to radiate.

7. Another complication may be the splitting of the bars into reticulations on the back and their intensification into larger spots along the sides.

PLATE XVIII.

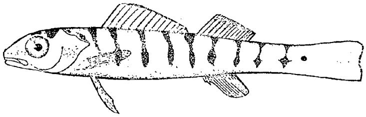


FIG. 1.

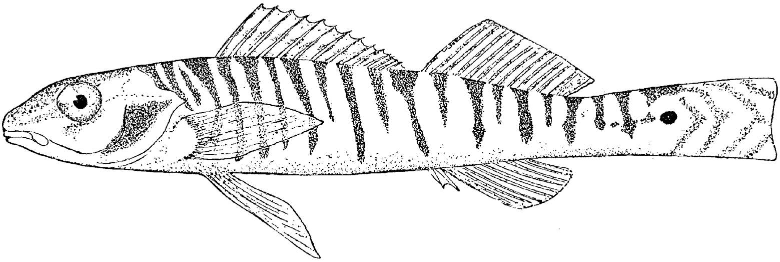


FIG. 2.

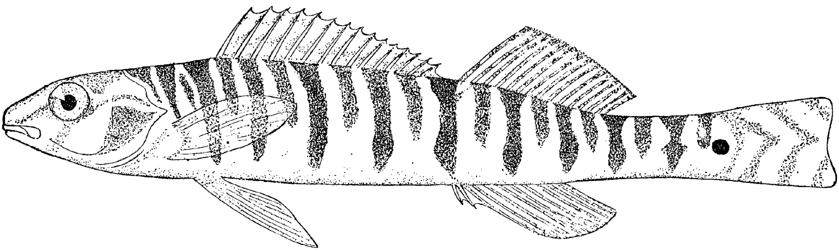


FIG. 3.

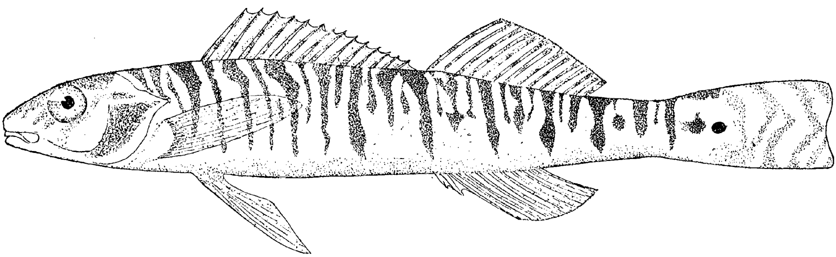


FIG. 4.

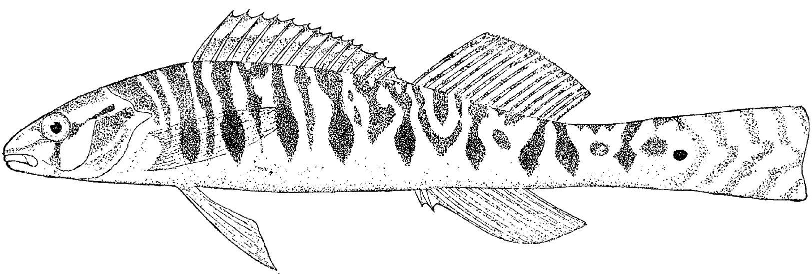


FIG. 5.

Etheostoma caprodes, Raf.

PLATE XIX.

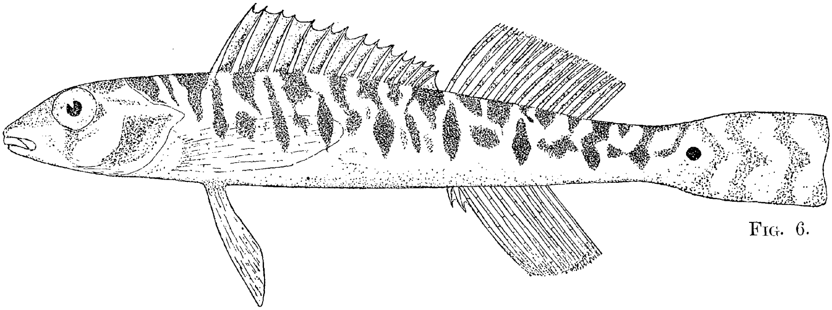


Fig. 6.

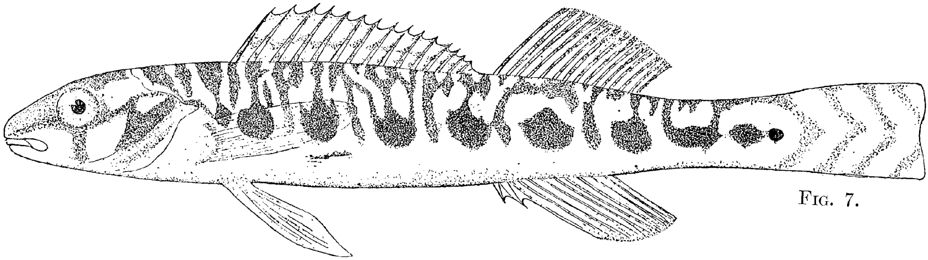


Fig. 7.

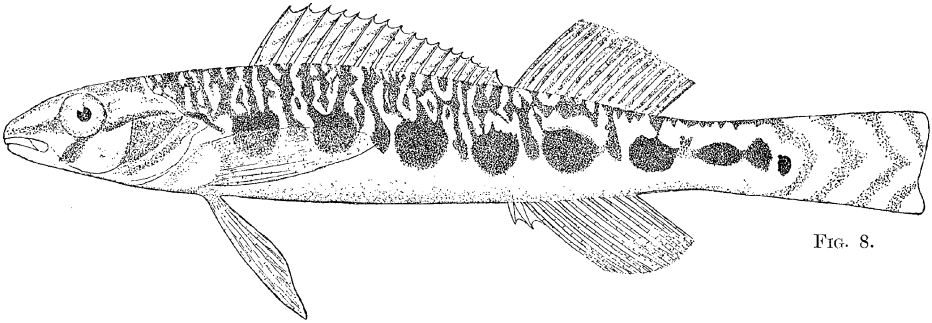


Fig. 8.

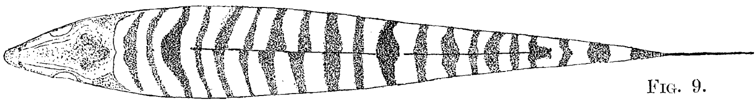


Fig. 9.

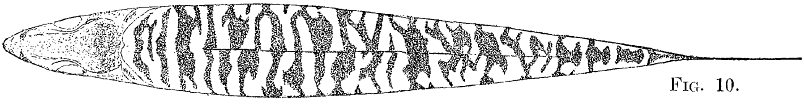
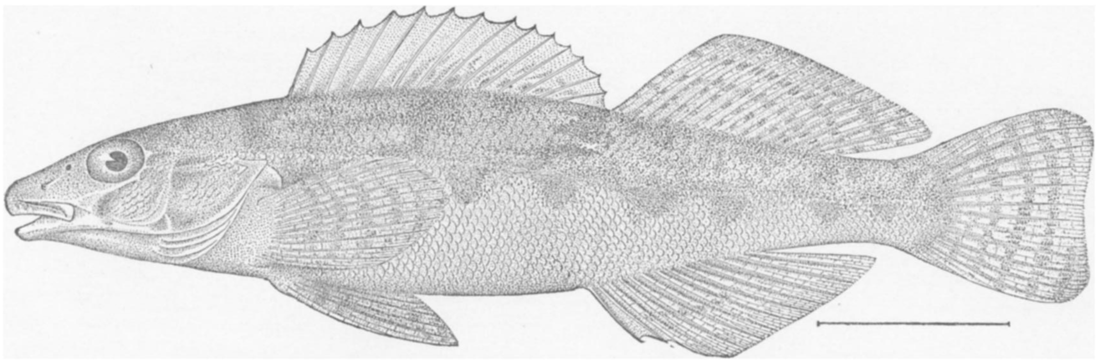


Fig. 10.

Etheostoma caprodes, Raf.

PLATE XX.



Etheostoma rex, Jordan.

PLATE XXI.

Distribution of Etheostoma caprodes.


75
Quebec
Port Neuf
Three Rivers
Berthier
Sorel
L'Orignal
Montreal
La Prairie
St. Johns
Beauharnois
Cornwall
St. Albans
Plattsburg
Burlington
Montpelier
Watertown
Rutland
Oswego
Rome
Saratoga Springs
Schenectady
Troy
Albany
Syracuse
Norwich
Ithaca
Owego
Hudson
Binghamton
Kingston
Towanda
Poughkeepsie
Newburg
New Haven
Scranton
Port Jervis
Pittston
Wilkesbarre
Stamford
Hazleton
Newark
NEW YORK
Brooklyn
New Brunswick
Easton
Allentown
Princeton
Lebanon
Reading
Trenton
Lancaster
Norristown
PHILADELPHIA
Camden
Chester
Wilmington
BALTIMORE
Annapolis
Dover
Easton
Norfolk
Portsmouth
Tarborough
40
35
30
26

8. Another modification is brought about by the shifting of the the lower half of the whole bars backward, which thus become separated from the dorsal halves. In this, the northernmost variety, the nape is naked.

9. In the simplest pattern, the two sides are usually symmetrical. If unsymmetrical, the asymmetry is introduced in the region of the spinous dorsal fin by a shifting forward or backward of the bars of one side in this region.

10. In the more complicated patterns the asymmetry has become the rule, and has spread along the region of both dorsals.

11. The variation in the combination of dorsal spines and rays is promiscuous.

12. The variation in the number of dorsal rays is promiscuous.

13. The variation in the number of dorsal spines is determinate. The southern specimens having a larger number of spines. Exception: the specimens from San Marcos Spring, Texas.

14. The variation in the number of anal rays is also determinate. As in the case of the dorsal spines, the number varies with the latitude, the southern specimens having a slightly larger number of rays.

Explanation of Plates.

Fig. 1. *Etheostoma caprodes Rafinesque,* 33 mm., Chocola Cr. Oxford, Ala.

Fig. 2. *Etheostoma caprodes Rafinesque,* 83 mm., Bean Blossom, Ind.

Fig. 3. *Etheostoma caprodes Rafinesque,* 88 mm., Chocola Cr., Oxford, Ala.

Fig. 4. *Etheostoma caprodes Rafinesque,* 102 mm., Green R., Greensburg, Ky.

Fig. 5. *Etheostoma caprodes Rafinesque,* 115 mm., San Marcos, Spr., Tex.

Fig. 6. *Etheostoma caprodes Rafinesque,* 88 mm., Torch Lake, Mich.

Fig. 7. *Etheostoma caprodes Rafinesque,* 86 mm., Obeys R., Elizabethtown, Tenn.

Fig. 8. *Etheostoma caprodes Rafinesque,* 115 mm., Lit. S. Fork Cumberland R., Wayne Co., Ky.

Fig. 9. *Etheostoma caprodes Rafinesque,* 60 mm., Gosport, Ind.

Fig. 10. *Etheostoma caprodes Rafinesque,* 85 mm., Obeys R., Elizabethtown, Tenn.

Fig. 11. *Etheostoma rex* Jordan.

Explanation of Map.

2. Pattern 2.
3. " 3.
4. " 4.
5. " 5.
6. " 6.
11. *Etheostoma rex* Jordan.